**Gain evaluation for low-density np/nB >1 proton- Boron fusion plasmas**

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**Abstract**

Fusion energy power plans based on compact magnetic fusion devices are funded in the USA and China [1, 2, 3]. For this type of devices, *p-11B* fuel is attractive, not only because of its corresponding aneutronic nuclear fusion reaction, which produces three (3) charged alpha particles of *8.7 MeV* total energy that can directly be converted into electricity, but also because it is not necessary to be equipped with breeding technologies for the production of the necessary components of the fusion fuel (p, 11B plenty abundant in nature). The last few years, power plans based on laser ignited fusion, have proposed the use of the *p-11B* fuel [4]. The disadvantages of the *p-11B* fuel are the Bremsstrahlung radiation losses and the fact that *p-11B* nuclear reaction presents a maximum at approximately 670 keV, which is high compared to the 10 keV ofD-T fuel. Theoretical works [5,6] investigate the interpretation of the relatively high alpha particle generation (1011) of the recent laser-based *p-11B* fusion experimental results [7, PALS facility], through the introduction of the chain reaction and the avalanche effect. The latter effects are responsible for the energy transfer from the fusion born alphas to the *p*, *11B* fusion species and the improvement of the reaction rate (RR). The use of a multi-fluid code enables us to evaluate the temporal evolution of the fusion medium parameters, the necessary time for the reaction rate (RR) maximization, the energy transfer from the produced alpha to the fusion species (*p*, *11B*), which results to an important increase of the energy of the latter to values corresponding to the optimum *p-11B* cross section and the contribution of the produced alphas density on the rapid rise of the RR [8, 9, 10, 11].. The numerical simulations concern initial densities of *10 19 – 10 20 m-*3, which are close to magnetic confinement fusion, and initial temperatures of the order of *80 keV* or lower, that are relatively low, compared to the energy corresponding to the maximum of the *p-11B* fusion cross section. In the present work, the initial density conditions are selected with a ratio of np/nb > 1, favorable for the Bremsstrahlung losses optimization. The numerical results show the importance of the chain reaction and the avalanche effect, that contribute to the feasibility of *p-11B* fusion ignition for relatively low initial medium temperatures. The gain evaluation for two distinct cases with density ratio of the fusion species *np/nΒ > 1* will be explored and compared: i) A *p-11B* fusion medium with initial temperature typically at *80 keV* and ii) The interaction of a Boron plasma of *80 keV* initial temperature with protons (proton fluid with energy lower than 1 MeV). These numerical results could be applied for potential experiments, using magnetic mirror-like configuration. Potential experimental set up with the related diagnostics will be presented and discussed.

 **References**

[1] T. J. Mcguire*,* “Heating plasma for fusion power using magnetic field oscillation”, US Patent 2014/0301519, 2014.

[2] N. Rostoker, M. W. Binderbauer, H. J. Monkhorst, “Colliding Beam Fusion Reactor”, SCIENCE, VOL. 278, p. 1119, 1997, https://tae.com/research-library

[3] ENN Compact Fusion Technology, http://en.ennresearch.com/researchfield/Compactfusion/

[4] H. Hora, S. Eliezer, G. J. Kirchhoff, N. Nissim, J. X. Wang, Y. X. Xu, G. H. Miley, J. M. Martinez-Val, W. McKenzie, and J. Kirchhoff, “Road map to clean energy using laser beam ignition of boron-proton fusion,” *Laser and Particle Beams,* vol. 35, no. 4, p. 730–740, 2017.

[5] S. Eliezer, H. Hora, G. Korn, N. Nissim, and Jos$`$ Maria Martinez-Val,“Avalanche proton-boron fusion based on elastic nuclear collisions”, *Physics of Plasmas*, vol. 23, p. 050704, 2016.

[6] F. Belloni, D. Margarone, A. Picciotto, F. Schillaci, and L. Giuffrida, “On the enhancement of p-11B fusion reaction rate in laser-driven plasma by a→p collisional energy transfer”, *Physics of Plasmas*, vol.25, no. 020701, 2018.

[7]C. Labaune, S. Deprierraux, S. Goyon, C. Loisel, G. Yahia, and J. Rafelski, “Fusion reactions initiated by laser-accelerated particle beams in a laser-produced plasma”, *Nature Communications*, vol. 4, Article ID 2506, https://doi.org/10.1038/ncomms3506, 2013.

[8] S. Moustaizis, C. Daponta, S. Eliezer, Z. Henis, P. Lalousis, N. Nissim and, Y. Schweitzer, “Alpha heating and avalanche effect simulations for low density proton-boron fusion plasma”, *Presentation in the 2nd International Workshop on proton-Boron fusion*, Catania, Sicily, 5-8 September 2022.

[9] S. Moustaizis, C. Daponta, S. Eliezer, Z. Henis, P. Lalousis, N. Nissim and, Y. Schweitzer, “Alpha heating contribution to the different stages of the p-11B fusion process and the temporal appearance of the avalanche effect”, Oral presentation at CHILI2022 (Conference on High Attosecond Laser Science in Israel), 5-8 December 2022.

[10] N. Nissim, Z. Henis, C. Daponta, S. Eliezer, S.D Moustaizis, P. Lalousis and, Y. Schweitzer, “Parametric scan of plasma parameters for optimization of the avalanche process in p11B fusion”, Oral *Presentation in the 2nd International Workshop on proton-Boron fusion*, Catania, Sicily, 5-8 September 2022.

[11] C. Daponta, S. Moustaizis, S. Eliezer, Z. Henis, P. Lalousis, N. Nissim and, Y. Schweitzer, “Numerical evaluations indicating p-11B high gain fusion due to important alpha heat transfer- avalanche effect, Poster presentation at CHILI2022 (Conference on High Attosecond Laser Science in Israel), 5-8 December 2022.